Can we foresee the impact of climate change on runoff, nutrient losses, river morphology and ecology in Denmark

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A CONWOY contribution
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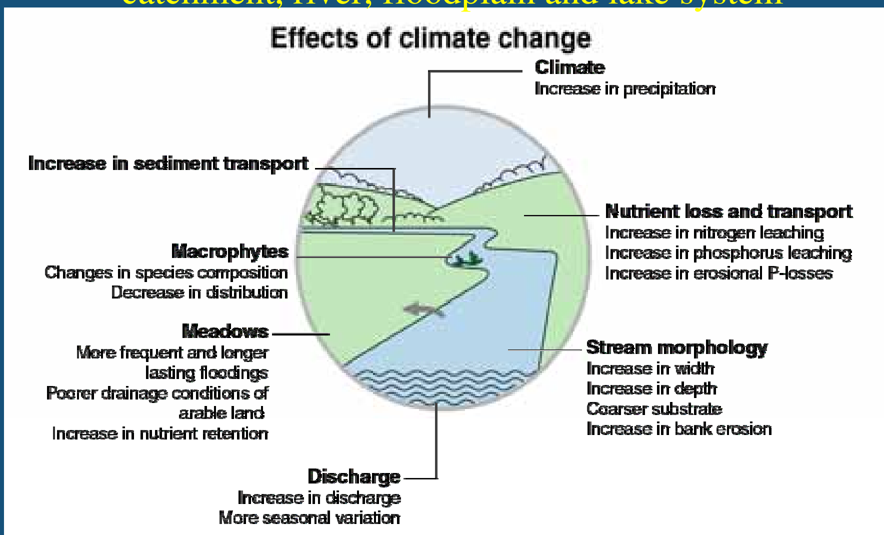
Potential impacts on the linked catchment, river, floodplain and lake system



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Hindcasting of precipitation and river hydrology

Hypothesis

- Mean annual precipitation has changed during the last century.
- River discharge will reflect these changes both annually, seasonally and in the case of extremes (peak flows, droughts).
- A gradient in precipitation and hence changes in discharge can be expected across Denmark.
- Changes in land use during the last century (arable land, drainage, urban areas, groundwater abstraction) could counteract or accelerate the climate signal on river hydrology.

Investigated:

5 climate stations (red)

17 river stations (blue)

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	Period	Catchment Area
		(km^2)
Western Jutland		
Brede Å	1921-2001	290
Ribe Å	1934-2001	675
Skjern Å	1920-2001	1055
Northern Jutland		
Lindenborg Å	1925-2001	214
Lindholm Å	1917-2001	106
Årup Å	1936-2001	105
Uggerby Å	1917-2001	153
Eastern Jutland		
Gudenå, Åstedbro	1917-2001	184
Gudenå, Tvilum	1917-2001	1282
Århus Å	1919-2001	119
Funen		
Odense Å	1917-2001	302
Brende Å	1918-2001	71
Zealand		
Saltø Å	1918-2001	64
Tude Å	1932-2001	148
Harrested Å	1921-2001	16
Suså, Holløse	1934-2001	763
Åmose Å	1920-2001	292
Tryggevælde Å	1917-2001	129

Other factors than climate influencing changes in runoff

- Land use changes during last century (drainage, urban development, agriculture, forest).
- Changes in drinking water and irrigation water consumption.

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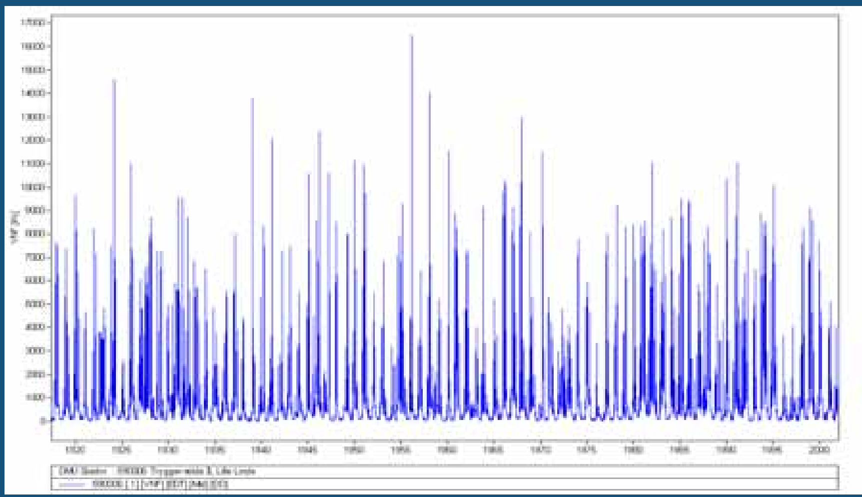
Daily mean discharge 1920-2001 Stream Tryggevælde (Zealand)



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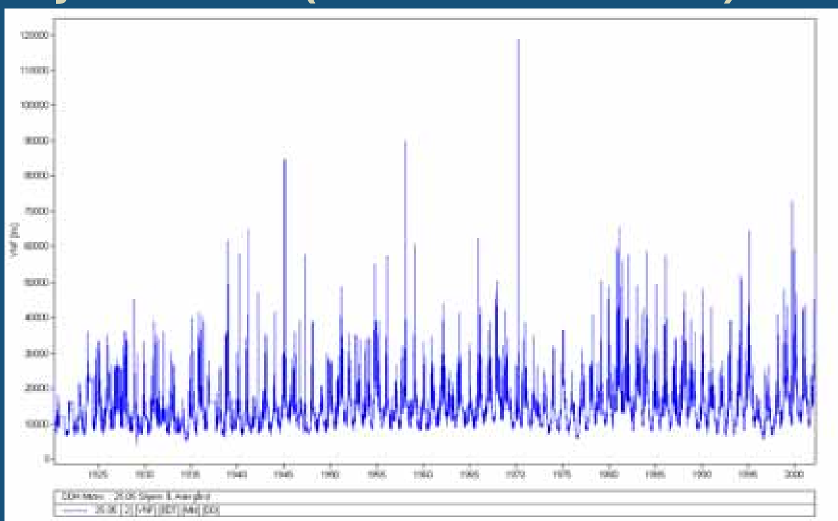
Daily mean discharge 1920-2001 Skjern river (western Jutland)



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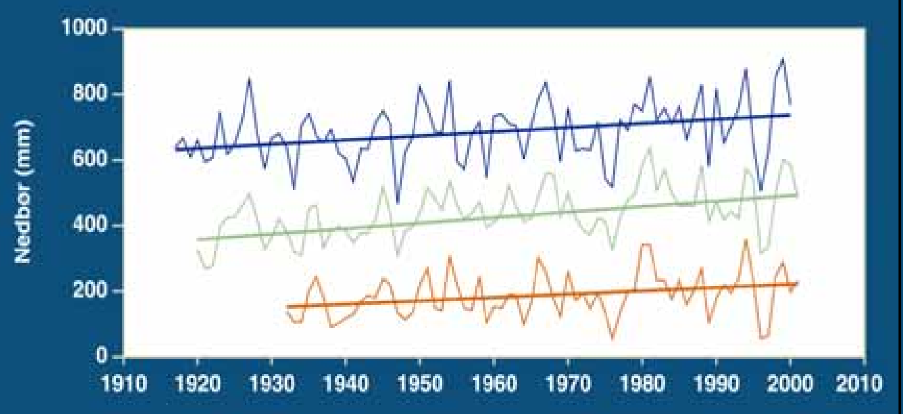
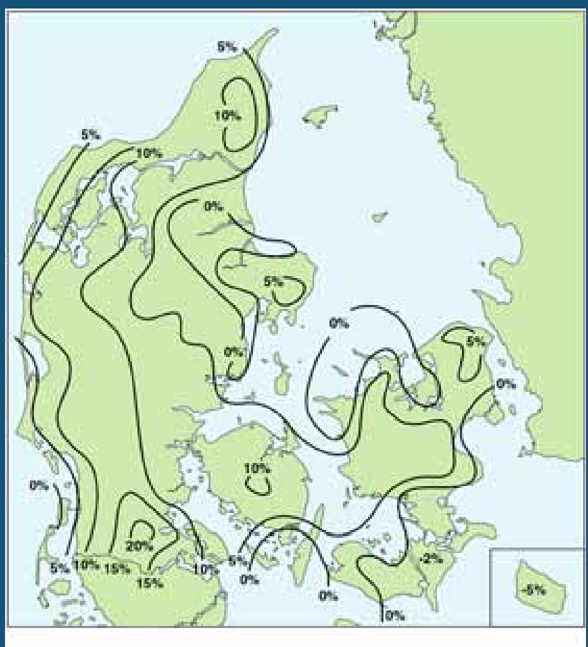
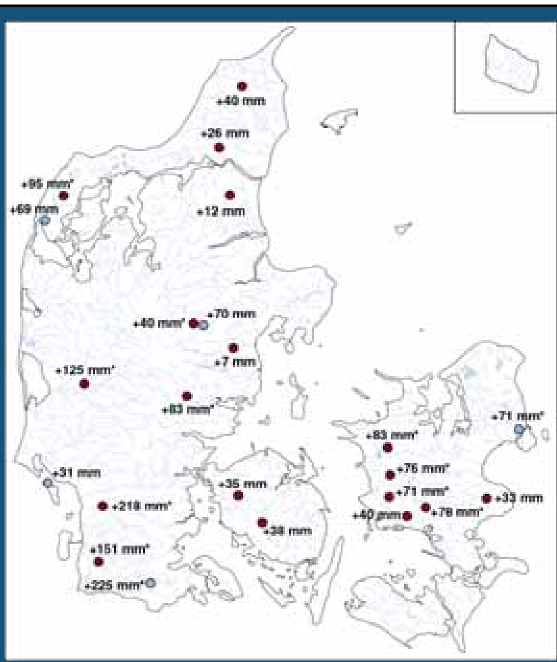
Udvikling i årlig gennemsnitsnedbør for Danmark (øverst), samt årsafstrømningen i henholdsvis Skjern Å (midt) og Tude å (nederst).





Changes in annual precipitation from 1931-60 to 1961-1990

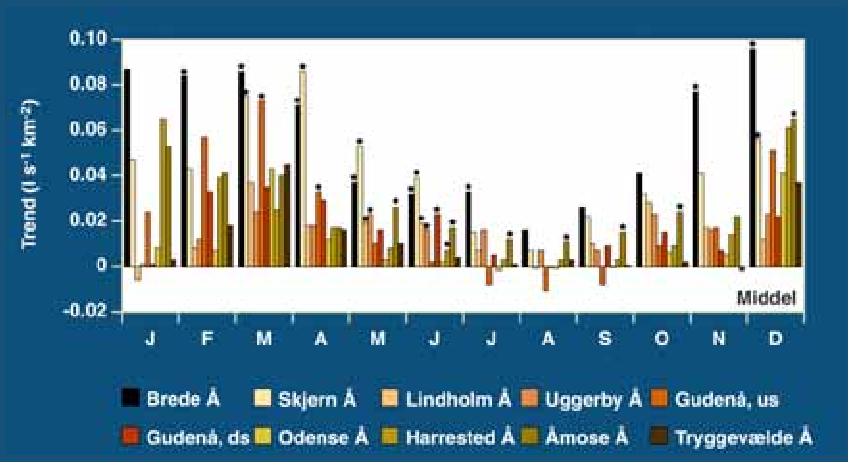


Changes in annual precipitation at 5 climate stations and runoff for Danish rivers during a 75 year period.

*Significant ($p \leq 0.05$)

Trend i nedbør over året ved forskellige målestationer

Trend i måneds middel afstrømningen i 10 vandløb



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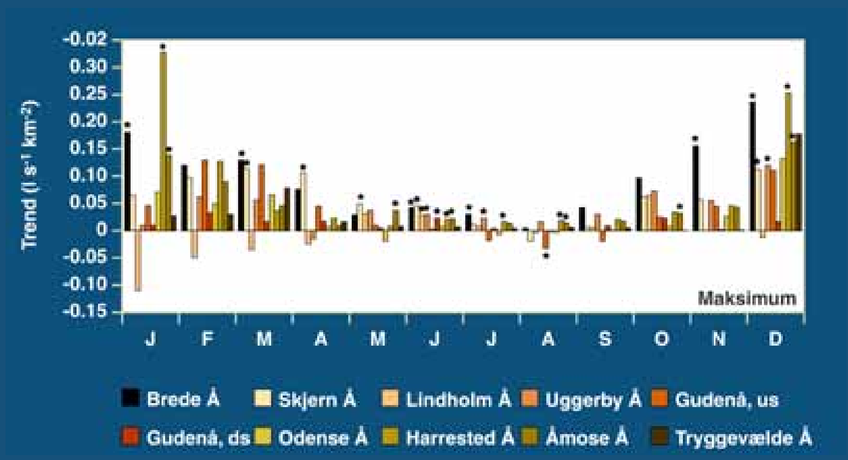
Trend i måneds maksimum afstrømningen i 10 vandløb



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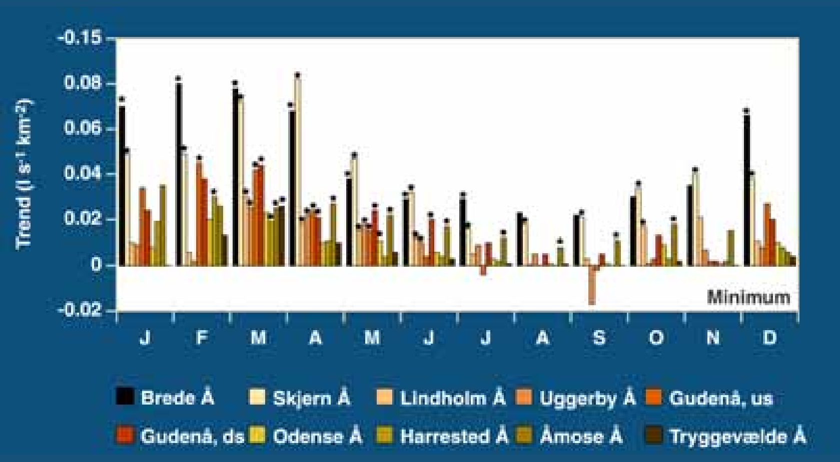
Trend i måneds minimums afstrømningen i 10 vandløb



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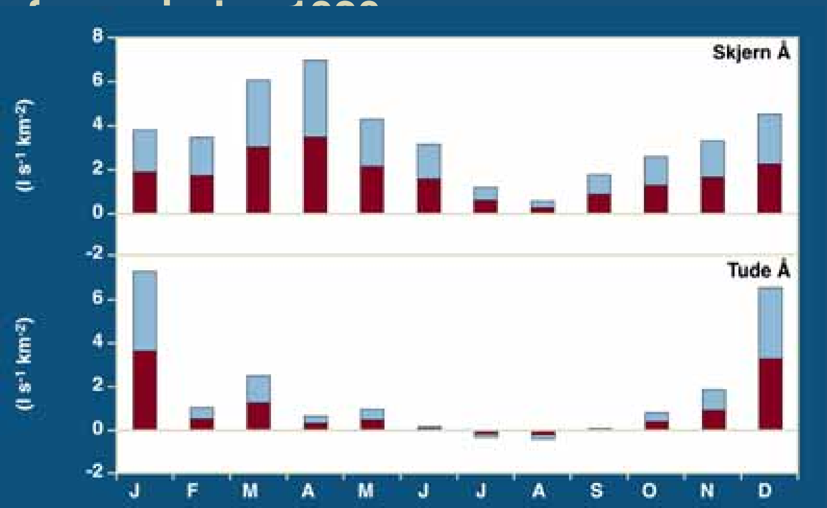
Hindcast 1920-2001 (rød) og fremskrivning (blå) 2001-2080 for ændring i måneds middel afstrømning i to vandløb



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River morphology and sediment transport

Hypothesis

- River morphology will adjust to changes in climate and hydrology.
- Adjustments will take place during and for a period following climate and hydrological changes before the river again will be in a dynamic equilibrium.
- Sediment transport will increase due to higher erosion and transport capacity/competence.
- Bank and bed erosion will increase.
- Substratum composition will change.

Regime models for undisturbed Danish streams in downstream direction

Stream width

Moraine landscape: $w = 4.83Q^{0.61}$

Outwash plain: $w = 5.59Q^{0.50}$

Stream depth

Moraine landscape: $d = 0.52Q^{0.47}$

Outwash plain: $d = 0.60Q^{0.39}$

Current velocity:

Moraine landscape: $v = 0.40Q^{-0.08}$

Outwash plain: $v = 0.30Q^{0.12}$

Mernild (2002) MSc Thesis, University of Copenhagen.

Suspended sediment response to climate change: an example

Q in m^3/s and C_{ss} in mg/l

Strongly rising stage: $C_{ss} = 80 \bullet Q^{1.72}$

Winter (Oct-May): $C_{ss} = 12 \bullet Q^{1.37}$

Summer (June-Sept.): $C_{ss} = 20 \bullet Q^{0.99}$

Kronvang (1992) Water Research 26(10).

Nutrient losses

Hypothesis

- Nitrogen leaching will increase due to higher mineralization and percolation of water through the root zone.
- Phosphorus leaching will increase due to higher mineralization and percolation of water through the root zone.
- Phosphorus loss will increase due to increase in overland flow (PP and DP).
- Phosphorus loss will increase due to increase in bank erosion.

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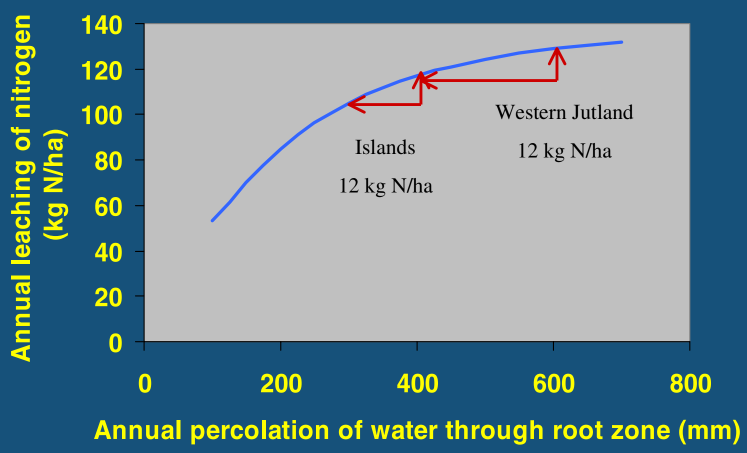
Climate change impact on nitrogen leaching from root zone



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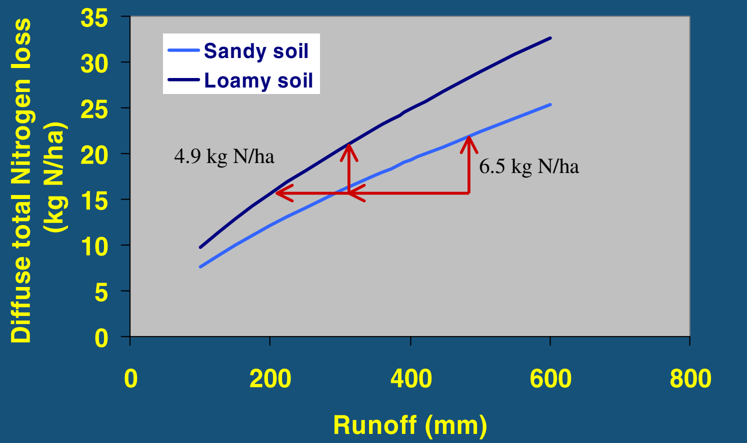
Climate change impact on diffuse total nitrogen loading of streams



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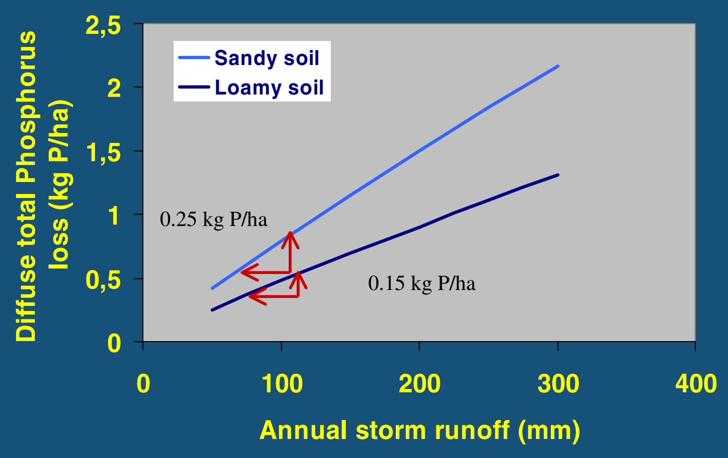
Climate change impact on diffuse total phosphorus loading of streams



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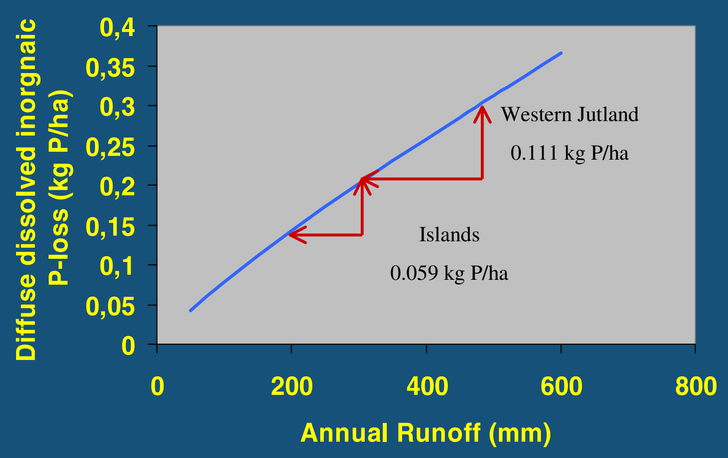
Climate change impact on diffuse dissolved P loading of streams



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Climate change impact on nutrient retention

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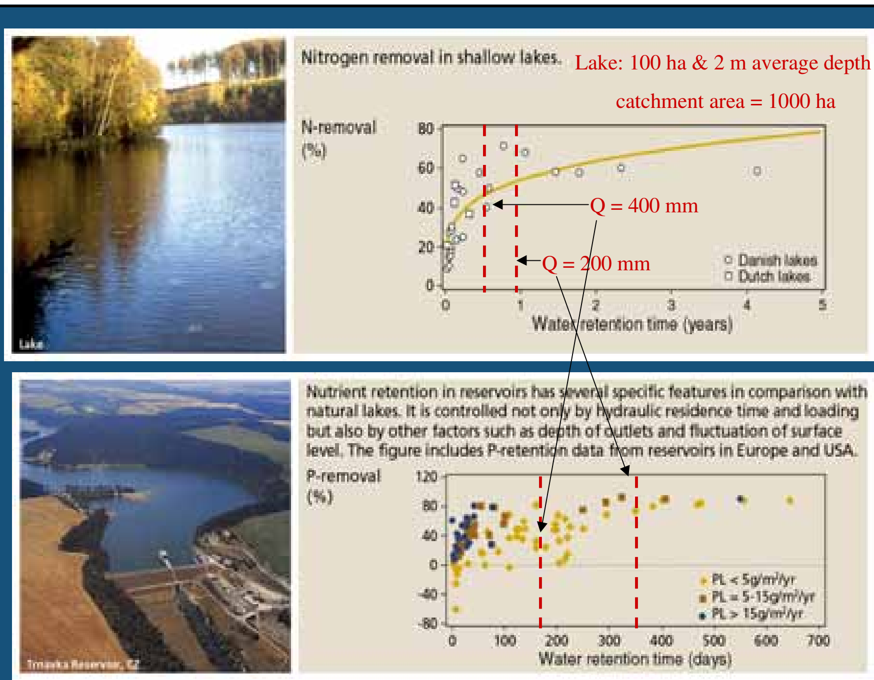

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Stream ecology

Hypothesis

- The changing hydrological regime in streams will impact the spatial and temporal extent of physical habitats and hence influence the biotic conditions.
- The more extreme hydrological conditions in streams, both high flow and low flow, will create larger physcial disturbances with adverse impacts on the biological structure and diversity.
- Rising stream water temperature will impact the species composition of macrophytes, invertebrates and fish in Danish streams.
- Indirect impacts on stream ecosystems will also occur caused by changes in catchment pressures (substances), concentration of dissolved oxygen in stream water, etc.

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River, lakes and floodplains

Research under the CONWOY project - WP2

- **Hindcast of changes in longer time series of daily discharge in a number of Danish rivers covering the west/east gradients in landscape and climate.**
- **Forecasting of changes in river discharge by applying hydrological models (NAM/MIKE11; MIKE-SHE/MIKE11.**
- **Analysis of changes in sediment mobilisation and transport applying erosion models and development of statistical models based on existing sediment concentration data.**
- **Analysis of changes in nutrient losses applying statistical and deterministic models.**
- **Analysis of changes in sediment and nutrient retention applying coupled hydrodynamic and nutrient retention model.**
- **Dating of sediment cores to analyse historical changes in sedimentation rates linked to climate/land use changes.**

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